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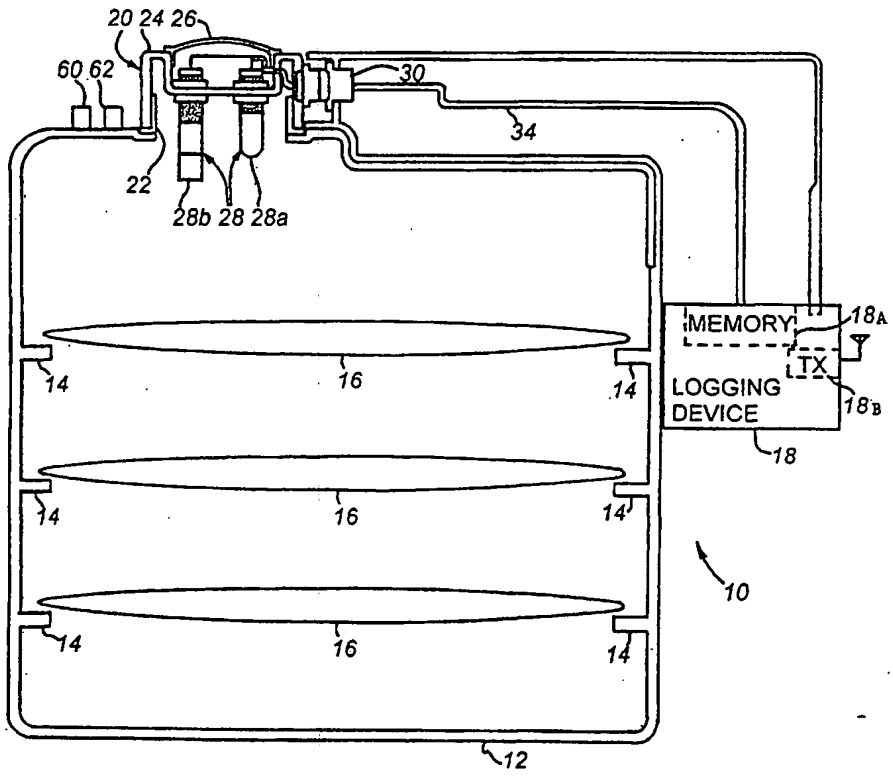
(54) Title: POD MONITOR FOR USE IN A CONTROLLED ENVIRONMENT

(57) Abstract

A system including a pod for carrying and storing objects and a device for monitoring the environment inside the pod and providing notification if the environment becomes less than desired. The monitoring device includes a sensor bundle connected to the pod for measuring the environment inside the pod and converting the measurements to electrical signals. The electrical signals are then provided to a logging device which stores them for later retrieval or transmission. If the electrical signals indicate an undesired environment, a signaling device may transmit a notification to an external system.



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POD MONITOR FOR USE IN A CONTROLLED ENVIRONMENT

Cross-Reference to Related Application

This is a non-provisional application claiming priority under 35 U.S.C. 119(e) from provisional patent application no. 06/050,455, filed June 23, 1997.

Field of the Invention

This invention relates to devices, called pods, SMIF PODS, FOUP'S or product carriers (called "pods" herein regardless of the industry in which used), used to provide a controlled (often clean room-like) environment for carrying objects such as semiconductor wafers or biologicals, and to monitoring the environment within a pod.

Background of the Invention

This invention relates to devices, called pods, used to provide a controlled (often clean room-like) environment for carrying objects such as semiconductor wafers, and to monitoring the environment within a pod.

Wafer fabrication facilities ("fabs") are required to provide extremely clean environments to permit correct processing of semiconductor wafers and to assure that the environment does not introduce significant defects on the wafers or affect yields adversely. Typically, all or most of the manufacturing processes take place in a clean room, and the environment in the clean room is carefully regulated. In addition, even within a clean room and certainly when transporting them to or from a clean room, the wafers often are stored and carried in a hermetically sealed wafer boat, or pod, to further prevent contaminants from coming in contact with the wafers.

However, because the pods are constantly being opened and closed for processing the wafers and the wafers are handled extensively in the course of processing (mostly by machine, but sometimes manually), the environment inside the pod often becomes unsatisfactory. Furthermore, defects may occur in a pod, such as leaks (induced, for example, by such handling or aging of seals), as a result of which the pod is no longer hermetically sealed and contaminants may then enter the pod. Even without defects in a pod, cross-contamination can occur between process steps, bringing into the pod undesired materials or elements. A single pod may contain wafers for integrated circuits that are worth, potentially, millions of dollars. Such circuits may cost a significant fraction of that amount to produce. Contamination, therefore, can be very

costly. Assuring that contamination has not occurred is important to assuring that the circuits on the wafer all will perform to specification and have a long life. Often, pods containing wafers not actively being processed are placed on workstations, indexers, or door openers or devices called stockers or modular equipment buffers, or the like. These devices may circulate an air flow through the pod, filter the flow and monitor the condition of the atmosphere exiting the pod. However, such devices are quite expensive and occupy a good deal of space. Consequently, pods containing wafers may be allowed to sit on shelves or otherwise not be connected to external monitoring equipment for considerable periods of time. If during that time unacceptable contaminants enter the pod, or the environment inside the pod otherwise becomes unsatisfactory, the wafers - or portions of them - may become compromised, even to the point of being unusable. However, if the pod environment were monitored continuously and the imminence of unsatisfactory conditions were detected, preventive measures might be available for holding off damage to wafers. For example, it may be desired to maintain a certain percentage of nitrogen in the atmosphere within the pod, to assure low humidity. If the nitrogen level drops below a threshold set to signal a problem (e.g., a leak), it may still be possible to recharge the atmosphere in time to prevent a serious problem.

To further complicate matters and provide an additional opportunity for contamination or physical damage, situations are now envisioned wherein it will be necessary to transport wafers from one location to another. During the course of such transport, the environment within a transport pod may deviate from allowable conditions. For example, the chemical composition of the environment or its physical characteristics, such as humidity or pressure, could become unsatisfactory due to leakage from the pod to the external environment or from the external environment into the pod. Or the pod and the wafers therein might be subjected to excessive vibration or other environmental factors. Not only is it important to protect wafers so that they are not subject to such potentially damaging conditions, but also it is necessary to detect when such conditions occur in order that liability for loss be attributable. The wafers in a pod being transported might be worth millions of dollars, for example. If the pod were mishandled by a shipper, the sender and insurer may want to recover damages. Otherwise, an insurer for a shipper may want to be able to prove that the damages did not occur while the wafers were in the shipper's custody. Accordingly, a need exists for monitoring the conditions in a pod, or those affecting a pod and its contents, at all times.

Summary of the Invention

Therefore the present invention provides a system that includes a pod for carrying and storing objects, such as semiconductor wafers, together with a device for monitoring the environment inside the pod. Preferably, the system further includes apparatus providing a (preferably periodic) time-stamping of the sensed environmental data and even notification (e.g., via a wireless transmitter) if the environment becomes, or threatens to become, less than desired. The monitoring device includes a bundle of one or more sensors connected to the pod for measuring the environment inside the pod and converting the measurement to electrical signals. The electrical signals are then provided to a logging device which stores (and preferably time stamps - again, preferably periodic) the data they represent for later (or contemporaneous) retrieval and/or transmission. If the data indicate an undesired environment or condition, a reporting device may transmit a notification to an external system.

According to a first aspect, the invention provides a system for providing a small, controlled environment for carrying or storing objects such as semiconductor wafers. The system comprises a pod for carrying and storing the objects, a sensor bundle containing at least one sensor adapted and arranged to measure the environment inside the pod and converting the measurement to electrical signals, and a logging device supported on the pod for receiving, sampling and recording at least some of the electrical signals.

Optionally, the system further includes a reporting device adapted to receive at least some of the recorded electrical signals and to transmit a message to an external system when any of said signals exceeds a predetermined threshold, signifying an undesired environment or the threat of one.

The invention may further include a snorkel device attached to the pod, said snorkel device facilitating the removal of samples of the environment in the pod.

An aspirator may be included for agitating the environment and preferably the sensor bundle can be easily removed and replaced.

The logging device may be a personal digital assistant ("PDA").

The logging device may include a signaling device and a processor operatively connected to the memory and to the signaling device, the processor being programmed to activate the signaling device to send an alarm signal in response to a measurement from a sensor exceeding a predetermined threshold. The signaling device may be a wireless transmitter.

According to another aspect, the system may include an optical recorder and an optical recording medium, the optical recorder being adapted to record on the optical medium process information relating to how the objects in the pod were processed. The recording medium may be inside or outside the pod.

An optical recorder and an optical recording medium also may be included, the optical recorder being adapted to record on and read from the optical medium process information relating to how the objects in the pod are to be processed.

According to still another aspect of the invention, a method is provided for maintaining the atmospheric conditions in a pod containing a semiconductor wafer. The method employs steps of monitoring at least one environmental parameter in the pod; generating a signal when a value of said parameter has a predetermined relationship to a predetermined value, signifying a present or threatened undesired environment; in response to said signal, moving the pod to a tool capable of changing the environment in the pod so as to change value of said parameter; and operating the tool to change the environment of the pod in a predefined way.

The pod initially may rest in a known location and after operating the tool, be returned to a predetermined location, which may be the same as said known location or different therefrom.

The pod may be moved to and from the tool by a robot or manually.

Brief Description of the Drawing

Fig. 1 is a diagrammatic side, partially cut-out view of an exemplary pod and measuring system embodying features of the present invention.

Fig. 2 is an isometric view of a pod such as may be used in the present invention, representative of a pod such as shown in Fig. 1.

Fig. 3 is an exploded view of a portion of Fig. 1, showing an alternative embodiment of a monitoring system according to the invention, illustrating a modified sensor bundle having a snorkel.

Fig. 4 is a top view of a diagrammatic illustration of the exemplary pod and measuring system of Fig. 1.

Fig. 5 is a cut away cross-sectional side view of a cap installed on the pod in place of a sensor bundle, taken along the section line A-A of Fig. 4.

Fig. 6 is a cut away cross-sectional side view of an optional aspirator which may be included in a pod according to the invention, taken along the section line B-B of Fig. 4.

Detailed Description of the Preferred Embodiment

Referring to Figs. 1 and 2 - 6, the reference numeral 10 refers to an exemplary pod and pod monitoring system embodying features of the present invention. The pod and monitoring system 10 includes a pod, or capsil, 12, comprising a housing which contains many elements of a conventional pod such as members 14 (which may be extrusions or separate pieces appropriately fastened to the interior wall of the pod) with which to hold and secure semiconductor wafers 16. The housing may be of any suitable material, but a transparent polymer may be particularly useful in some situations. The system 10 also includes a logging device 18. Minimally, logging device 18 includes a memory device 18A and interface circuitry (not shown) connecting the memory device to receive input from sensors, and for obtaining data output from the memory. In an exemplary embodiment, the logging device may include a personal digital assistant ("PDA"). The PDA 18 may perform conventional functions such as logging processing operations for tracking the pod through the semiconductor fabrication process, and/or reporting through wireless communications information about the pod to a central reporting facility. If the logging device includes a PDA, the aforesaid memory may be contained within the PDA. Alternatively, in order to share the cost of a PDA or like equipment among a number of pods, logging device 18 may employ a separate memory device which collects and logs data from sensors and which is interfaced from time to time to a removable PDA or like device. The PDA may be attached at intervals (i.e., from time to time) to read the memory and collect or transmit data to other points (e.g., via a wireless modem or other suitable transmitter 18B). In this way, a single PDA might be shared and moved from pod to pod.

At the top of the pod 12 is a monitoring system 20 which interfaces to the logging device 18. The monitoring system 20 attaches to the pod 12 on a threaded collar 22. The monitoring system includes a threaded sensor cap 24, a sensor bundle trim cap 26, a sensor bundle 28 including (for example) two transducers 28a, 28b, a connector 30 and a bus 34. (While two transducers 28a and 28b are illustrated for purposes of exemplification, it will be appreciated that the invention is not limited to any particular number of sensors or transducers.) The monitoring

system 20 can be replaced, if desired, by a simple threaded cap 40. In addition, the transducers 28a, 28b may be self-contained, containing or providing their own calibration data. In this way, if the PDA 18 is ever disconnected, the transducers will not suffer any loss of accuracy as a result thereof.

When in place, the sensors in bundle 28 can detect or monitor various components of the environment inside the pod 12, such as light intensity or spectrum, fluid velocity, pressure, organisms, chemicals, particles, temperature, humidity, gases, static charges, visual effects, vibration and acceleration. The sensor bundle 28 converts these detections to electrical signals and provides the electrical signals to the memory 18A through the connector 30 and the bus 34. The memory then logs the electrical signals and preferably time stamps them. The logging device, when connected, produces warnings and/or alarms as required. Of course, the logging device typically will include, or there will be provided external to the logging device, analog to digital converters to convert the typically analog sensor signals into digital signals usable by the memory 18A.

Referring to Fig. 3, in an alternative embodiment, a monitoring system 20' contains a sensor bundle 28' including a first transducer 28a and a snorkel 28c. The snorkel 28c is a hollow tube topped with a cap or membrane or check valve 28d which can be removed so that samples of the environment inside the pod 12 can be withdrawn or sensor can be inserted.

In another alternative embodiment, an aspirator 50 is included inside the pod 12, typically at the bottom of the pod (indicated in Fig. 4 by the dashed circle 51). The aspirator 50 includes an air circulation device 52 that moves or agitates the air around the sensor(s) 28a, filters 54, an inlet check valve 56 and one or more outlets 58. A sensor bundle 28 or 28' (including sensor(s) 28a) may be adjacent to, opposite, or contained inside the aspirator 50. The gaseous environment of the pod is drawn through a check valve into the aspirator 50 by circulation device 52, via inlet 56, and is exhausted back into the pod after passing through filter 54 via outlet(s) 58. This flow facilitates sensing of the gaseous atmosphere of the pod by the sensor bundle.

Maintenance of the atmosphere within a pod is extremely important to maintaining the integrity of the semiconductor wafers 16. Whether leaks or chemical activity are responsible, the environment within a pod which is sitting idle while in WIP, between processing steps, for example, will change over a period of time. The present invention provides apparatus which can monitor the environment inside the pod in real time. For example, one of the sensors in the

sensor bundle may a nitrogen sensor and logging device 18 may be configured to transmit to a central facility a signal calling attention to the pod if the nitrogen level drops below a predetermined threshold. Alternatively, a humidity sensor may be provided and logging device 18 may be configured (e.g., programmed) to transmit to a central facility or purging apparatus a signal calling attention to the pod if the humidity level exceeds a predetermined threshold. Appropriate action may then be taken to purge the pod's environment with additional N_2 gas. With sensing external to the pod, as is customary, this is not possible unless the pod is connected all the time to the external sensing arrangement. Since such external sensors typically are included in expensive equipment such as the Inertra Purging System from Semifab Inc. of Hollister, California, it has previously been necessary to dedicate very large and expensive equipment to this task.

When the sensors indicate a need to purge the pod environment, a pod may be removed manually from its resting place and transported to an appropriate purging station (generically called a "tool"), or a robotic manipulation system may remove the pod from its resting place, install the pod on the tool, allow the tool to purge the pod and then return the pod to a resting place upon completion of the operation. This further allows time-sharing of the tool.

A further benefit of the invention is that data may be time-stamped as it is generated and collected in the memory. In turn, if desired, the data can be read by an external system and then written back to the wafer or wafers in the pod. For example, a laser 60 (either inside or outside the pod wall, assuming the wall is transparent) may be controlled to scribe on the wafer (typically the top wafer or alternatively a writeable medium such as that used for CD/R devices, placed above the top wafer or monitor wafer on the side of the pod or in another convenient location) any desired information such as an identification of the processing used or to be used to fabricate the wafer, etc. The data could also be written to a label which can be placed on the pod or on a tag attached to the pod, for example. Thus, very complete records can be assembled for the wafers in the pod. This may be particularly advantageous when the pod is used for shipping wafers. By periodically sampling the conditions in the pod and of the pod, and logging that data, both the sender and the shipper can guarantee to the receiver that proper conditions were maintained throughout shipment. Or, alternatively, if a problem is found upon receipt, liability can be allocated in accordance with the data. Perhaps of even greater significance, when a pod is placed on a test stand or work station and the sensing of its environment then shows there to have

been some contamination, one has little or no idea of the actual source of molecular contamination. With the present invention, by contrast, constant monitoring facilitates easy ascertainment of the time contamination occurred as well as facilitating prompt and definite identification of the contamination source. In turn, that may allow users to avoid contaminating other pods and their wafers or alert them of a mishandling event.

A further option is to include on the pod housing, probably on the outside, an optical reader 62 and to encode each wafer, during manufacture, with identifying indicia which can be read by the reader when the wafer is inserted or removed from the pod.
(At other times, one wafer may obscure another wafer, so it may not be possible to read all of the wafers.)

The foregoing illustrative embodiments of the invention have been shown and described by way of example only. Modifications, changes, and substitutions are intended to be suggested by the foregoing disclosure. For example, with optical read/write systems for recording data on the objects in the pod or their processing, an image can be projected to the pod or capsil walls or door and extracted via a receptor on the robot arm or end-effector, or an image may simply be projected directly on or into the tool and it's resident receptor. Alternatively, instead of using an optical system for this read/write function, a magnetic strip could be utilized. The magnetic strip can be placed in any convenient location, such as on the door of the pod, where it would be accessible to a tool. Accordingly, it is appropriate that the appended claims be construed broadly and in a manner consistent with the scope of the invention described. The invention is intended to be limited only by the appended claims and equivalents thereto.

What is claimed is:

CLAIMS

1. A system for providing a small, controlled environment for carrying or storing objects such as semiconductor wafers, the system comprising:

a pod for carrying and storing the objects;

a sensor bundle containing at least one sensor adapted and arranged to measure the environment inside the pod and converting the measurement to electrical signals; and

a logging device supported on the pod for receiving, sampling and recording at least some of the electrical signals.

2. The system of claim 1 further including a reporting device adapted to receive at least some of the recorded electrical signals and to transmit a message to an external system when any of said signals exceeds a predetermined threshold.

3. The system of claim 1 or claim 2 further comprising a snorkel device attached to the pod, said snorkel device facilitating the sampling of the environment in the pod.

4. The system of claim 1 or claim 2 further comprising an aspirator for agitating the environment to facilitate sensing.

5. The system of claim 1 or claim 2 wherein the sensor bundle can be easily removed and replaced.

6. The system of claim 1 or claim 2 wherein the logging device is a personal digital assistant ("PDA").

7. The system of claim 1 or claim 2 wherein the logging device includes a signaling device and a processor operatively connected to the memory and to the signaling device, said processor being programmed to activate the signaling device to send an alarm signal in response to a measurement from a sensor exceeding a predetermined threshold.

8. The system of claim 7 wherein the signaling device is a wireless transmitter.

9. The system of claim 8 further including an optical recorder and an optical recording medium, the optical recorder being adapted to record on the optical medium process information relating to how the objects in the pod were processed.

10. The system of claim 9 wherein the recording medium is within the pod.

11. The system of claim 8 further including an optical recorder and an optical recording medium, the optical recorder being adapted to record on and read from the optical medium process information relating to how the objects in the pod are to be processed.

12. The system of claim 9 wherein the recording medium is within the pod.

13. A method of maintaining the atmospheric conditions in a pod containing a semiconductor wafer, comprising the steps of:

a. monitoring at least one environmental parameter in the pod;

b. generating a signal when a value of said parameter has a predetermined relationship to a predetermined value, signifying a present or threatened undesired environment;

c. in response to said signal, moving the pod to a tool capable of changing the environment in the pod so as to change value of said parameter; and

d. operating the tool to change the environment of the pod in a predefined way.

14. The method of claim 13 wherein, prior to step c, the pod rests in a known location and further including the step of:

e. after operating the tool, returning the pod to a predetermined location, which may be the same as said known location or different therefrom.

15. The method of claims 13 and 14 wherein the steps of moving and returning are performed by a robot.

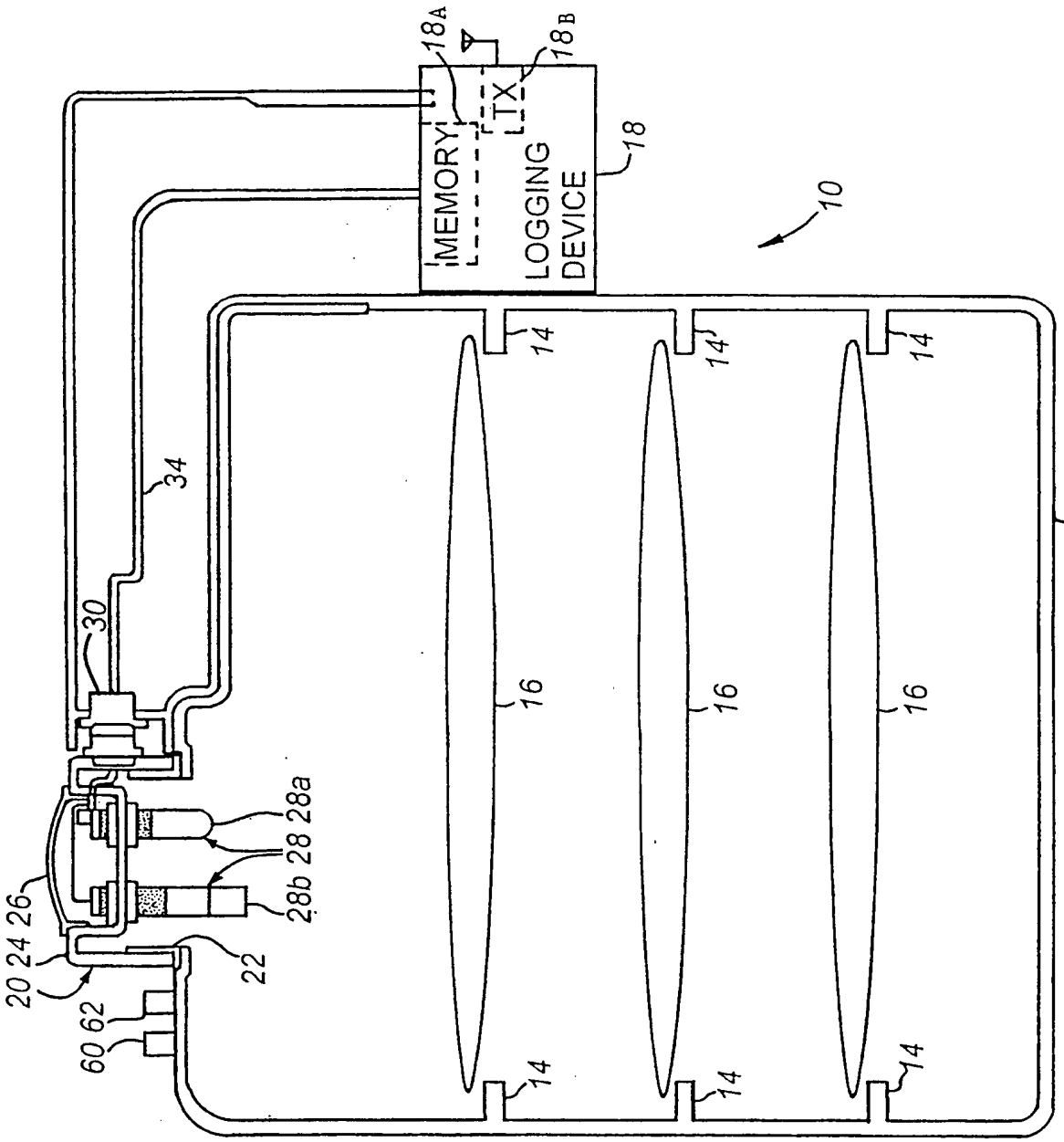

Fig. 1

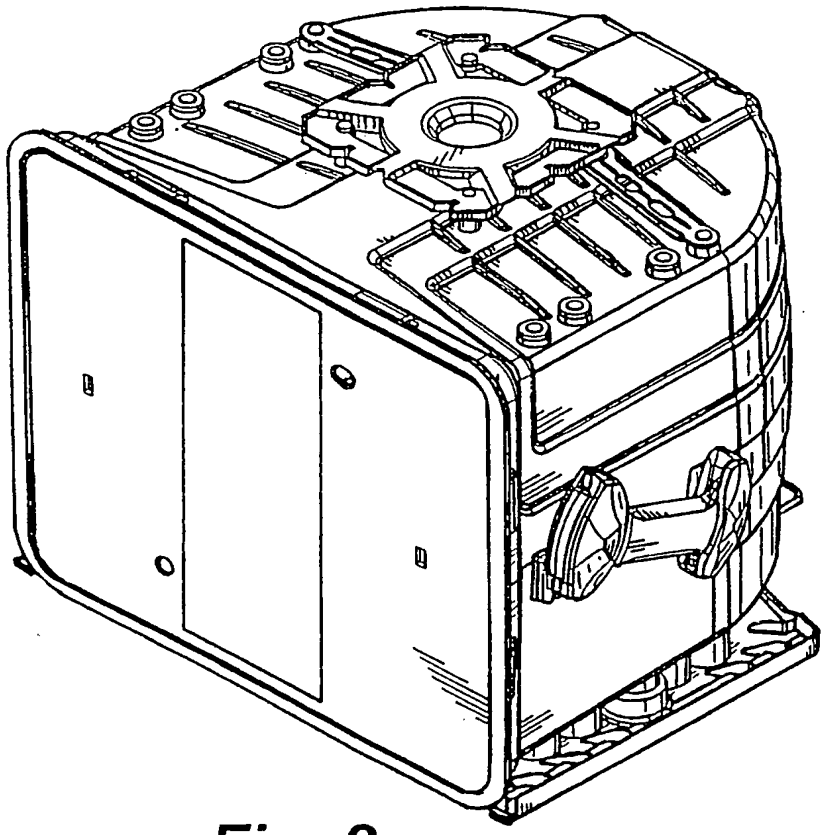

Fig. 2
(PRIOR ART)

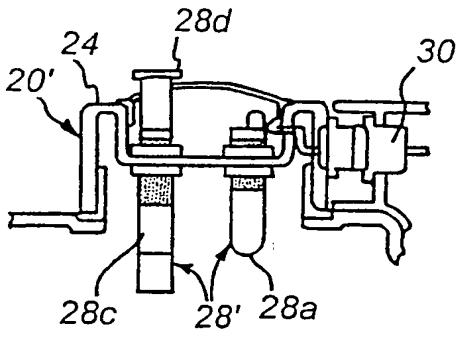

Fig. 3

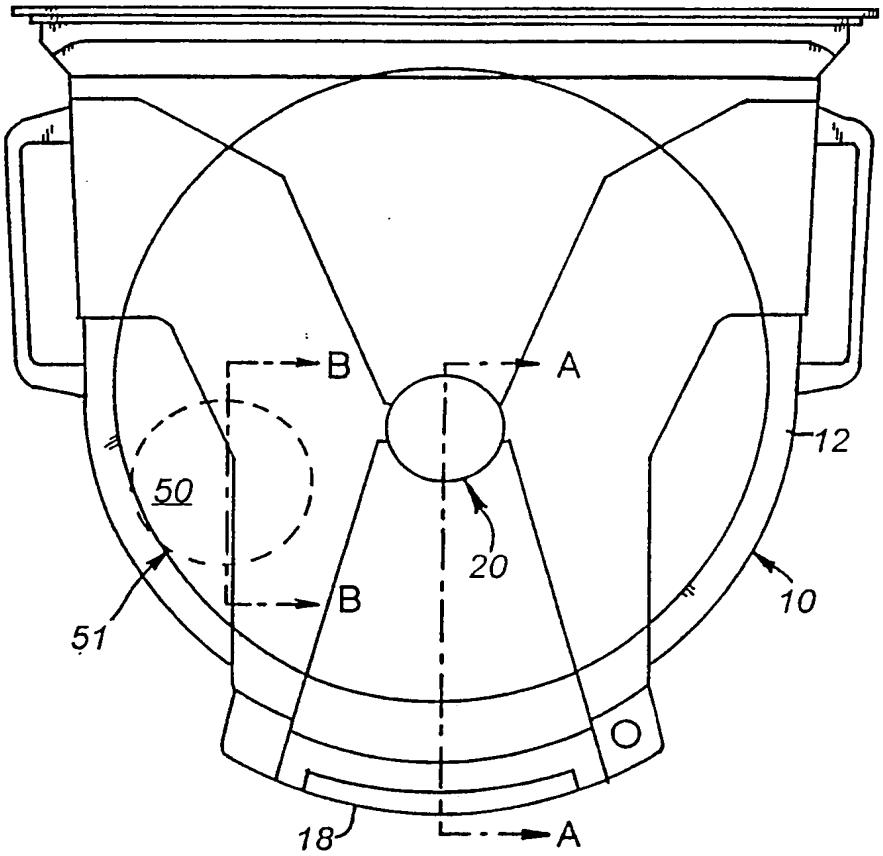

Fig. 4

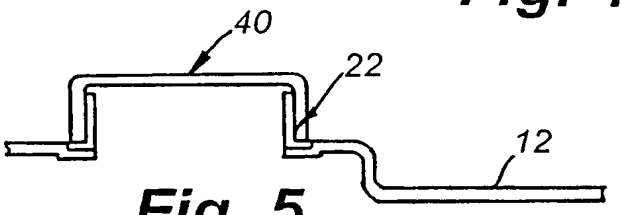

Fig. 5

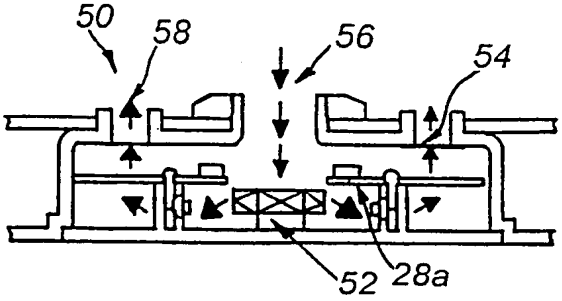

Fig. 6